TWO STRATIGRAPHICALLY IMPORTANT *NUMMULITES* SPECIES FROM THE MIDDLE EOCENE OF INDIA AND EUROPE

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ABSTRACT. *Nummulites obtusus* (Sowerby) is redescribed and re-illustrated from the type area in India, and its morphology is discussed. Topotypes of *N. perforatus* (de Montfort) from Romania are also described and figured and the two species are shown to be distinct and to belong to different lineages. *N. perforatus* is restricted to the late Middle Eocene (*Truncorotaloides rohri* Zone) while *N. obtusus* occurs in the middle Middle Eocene (*Globorotalia lehneri* Zone).

Numularia obtusa was erected by Sowerby (1840) from Waghapadar in Cutch, western India. Unfortunately, he did not describe the species adequately, but provided only a brief diagnosis in the plate explanation. Consequently, some later workers on European *Nummulites* treated *N. obtusus* as a junior synonym of *Nummulites perforatus* (de Montfort) described from Romania in 1808. This was accepted by several workers on Indian *Nummulites*, including those who re-examined *N. obtusus* from Cutch. Thus, Nuttall (1926, p. 138) remarked: 'The nomenclature of this species has been in a state of considerable confusion. The form was at first called *N. perforatus* by D'Archiac and Haime as well as by de la Harpe, and later by other writers *N. crassus* and *N. aturicus*. Of recent years the name *N. perforatus* has been employed for the megalospheric and *N. obtusus* for the microspheric form.' Recently, Sen Gupta (1965) also treated *N. obtusus* as a junior synonym of *N. perforatus*.

This paper describes and evaluates *N. obtusus* from well-preserved and abundant material from Cutch. Topotypes of *N. perforatus* are also described, and the distributions of the two species are discussed. All the specimens are deposited in the writer's collection in the Geology Department, University of Calcutta.

MATERIAL AND METHODS

The Lower Tertiary succession in Cutch comprises the Matanomadh Formation, Naredi Formation, Harudi Formation, Fulra Limestone, and Maniyara Fort Formation in ascending order (Biswas and Raju, 1971). *Nummulites* occurs in all except the Matanomadh Formation, but *N. obtusus* is restricted to the Harudi Formation. It is concentrated in a two-foot thick clayey limestone band occurring about 16 ft below the top (Biswas and Raju, 1973). This band is well-exposed in the Lakhpat area in northwestern Cutch (Sen Gupta, 1959, 1964). The yellowish grey *N. obtusus* rock has been strongly lateritized. The Eocene succession in the Lakhpat area is summarized in Table 1. The samples for this study were collected from the two outcrops of *N. obtusus* band near Lakhpat (text-fig. 1). Abundant free specimens were available. Preservation of the material was satisfactory enough to permit detailed examination of internal and external structures.

Topotypes of *N. perforatus* (de Montfort) from Romania were provided by Mr. M. K. Sen of the Geological Survey of India, Calcutta. Guided by Dr. Nicolae Meszaros of the University of Babes-Bolyai, Romania, Mr. Sen made collection from the *Nummulites perforatus*-band exposed near the village of Leghia near Cluj in 1976–1977. This is believed to be the type locality for *N. perforatus* (Bombiţâ *et al.* 1975, p. 164).

Some specialists have used split specimens of *Nummulites* in order to study the features of the equatorial plane, while many others including most Anglo-American workers preferred thin sections. Pioneering workers such as d'Archiac and Haime (1853) held the view that for the proper understanding it was necessay to examine equatorial as well as axial sections of *Nummulites*. However, a group of authors including Schaub (1951) did not consider it essential to study the test in axial section. These different methods of study have considerably affected the identification of the species of this important Lower Tertiary genus.

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TABLE 1. Eocene succession in Lakhpat area, northwestern Cutch, Gujarat.

Geological Age		Rock-Stratigraphical units	Lithology and thickness	Fauna	Environment of deposition
Oligocene		Maniyara Fort Formation			
		Paraconformity			
EOCENE	Middle	Fulra Limestone	Massive to thickly bedded, cream to dirty white and buff coloured foraminiferal limestone. 25 m	Very rich in larger as well as planktonic foraminifera	Middle shelf
		Disconformity			
		Harudi Formation	Yellowish grey foraminiferal limestone, lateritized, with thin bands of gypsum at places. 3 m	Larger foraminifera common	Inner shelf
		Disconformity			
	Lower	Naredi Formation	Ferruginous claystone strongly lateritized. 2 m	Devoid of fauna	Non-marine
		Unconformity			
		Deccan Trap			

The difficulty in satisfactorily examining features of the equatorial plane in thin section has been pointed out by earlier authors. Nuttall (1926, p. 140) in describing *Nummulites maculatus* remarked, 'The shell . . . is rarely flat, being often curved near the edge, so that it is nearly impossible to obtain a complete thin equatorial section of the chamber layer.' The merit of using split specimens is thus easily understood.

Although several authors have used lateral sections to show the characters of the septal filaments, they are satisfactorily examined only on the surfaces of decorticated specimens. Width of the equatorial chambers, character of the spiral lamina from pole to periphery, alar prolongations, and the development and nature of pillars and polar plugs are best examined in axial sections. Even if these features are considered less significant than those seen externally or in the equatorial plane, axial sections should be illustrated when new taxa are described. In the present work surface features were examined on decorticated specimens and internal features by split specimens and axial sections. In both *N. obtusus* and *N. perforatus* the equatorial plane is gently curved making it difficult to examine satisfactorily its characters in thin section.

SYSTEMATIC PALAEONTOLOGY

Order FORAMINIFERIDA
Family NUMMULITIDAE de Blainville, 1825
Sub-family NUMMULITINAE de Blainville, 1825
Genus NUMMULITES Lamarck, 1801
Nummulites obtusus (Sowerby)

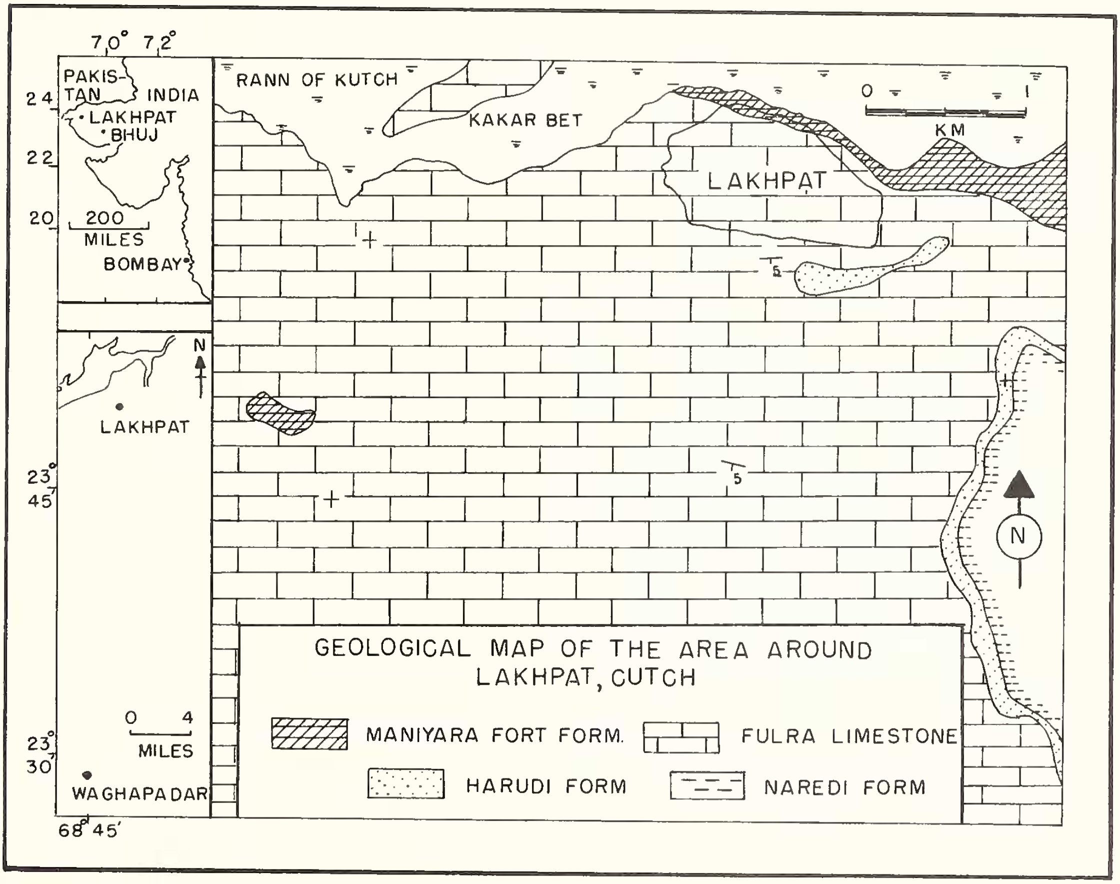
Plate 113, figs. 3–5; Plates 114 and 115

1840 *Nummularia obtusa* Sowerby, p. 329, pl. 24, fig. 14. Not fig. 14*a*.
1853 *Nummulina obtusa* (Sowerby); Carter, p. 170, pl. 7, figs. 13, 14.
1853 *Nummulites obtusa* (Sowerby); d'Archiac and Haime, pp. 122, 123, pl. 6, figs. 13*a–c*.
1879 *Nummulites perforata* var. *obtusa* (Sowerby); Rupert Jones in Blanford, p. 10.
1879 *Nummulites obtusa* (Sowerby); Medlicott and Blanford, p. 459, pl. 15, fig. 13.
1906 *Nummulites gizehensis* var. *obtusus* (Sowerby); Vredenburg, p. 85.
1940 *Nummulites obtusus* (Sowerby); Davies, p. 212, pl. 11, fig. 14.
1965 *Nummulites perforatus* (de Montfort); Sen Gupta, pp. 93–95, pl. 16, figs. 1, 2, 11; pl. 17, figs. 3, 9, 10, 13; text-fig. 2.

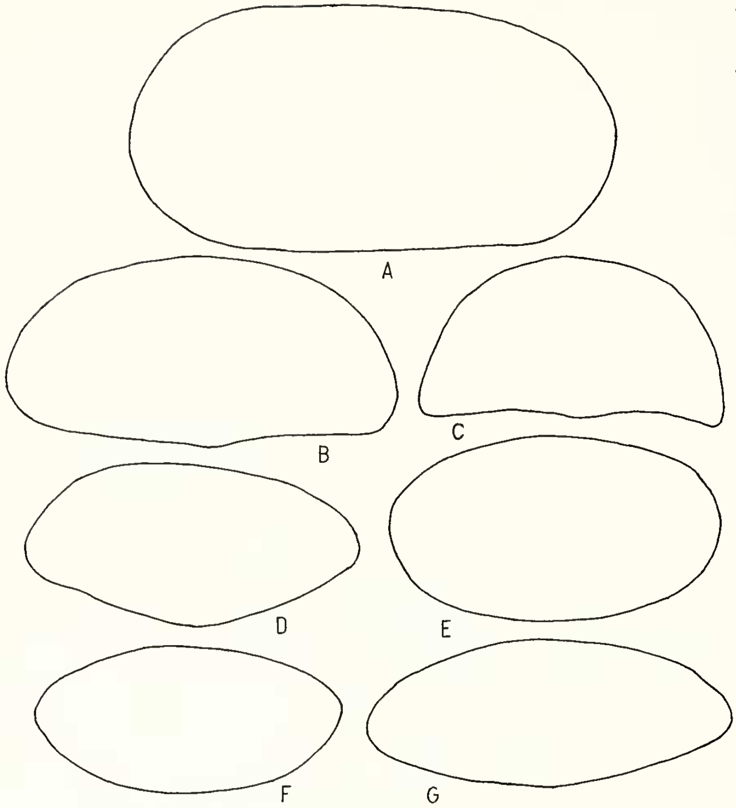
Microspheric generation. Material. Fifty-two isolated specimens, ten split specimens and ten axial sections were examined.

Description. External features. Test lenticular to nearly globose (text-fig. 2). Smaller specimens usually flat lenticular with gently sloping sides. With increasing size the test becomes thicker and the polar region flattens. In extreme cases, the sides become sub-parallel. One side is often more flattened than the other. In both thick and thin specimens the edge of the text is often flexed producing concavo-convex to reniform transverse outline. Rarely, a narrow, ridge-like thickening, confined to one side, occurs on the surface. The margin also varies considerably. In flatter specimens it is usually angular. Occasionally, the marginal cord forms a narrow rim. In thick specimens the margin is obtuse—hence the species name. Thick specimens with sub-parallel sides have bluntly rounded margins, and axial sections of such specimens resemble *Alveolina* in outline (see Pl. 114 fig. 4). Test diameter ranges from 7·9 mm to 22 mm and thickness from 2·9 mm to 10·6 mm.

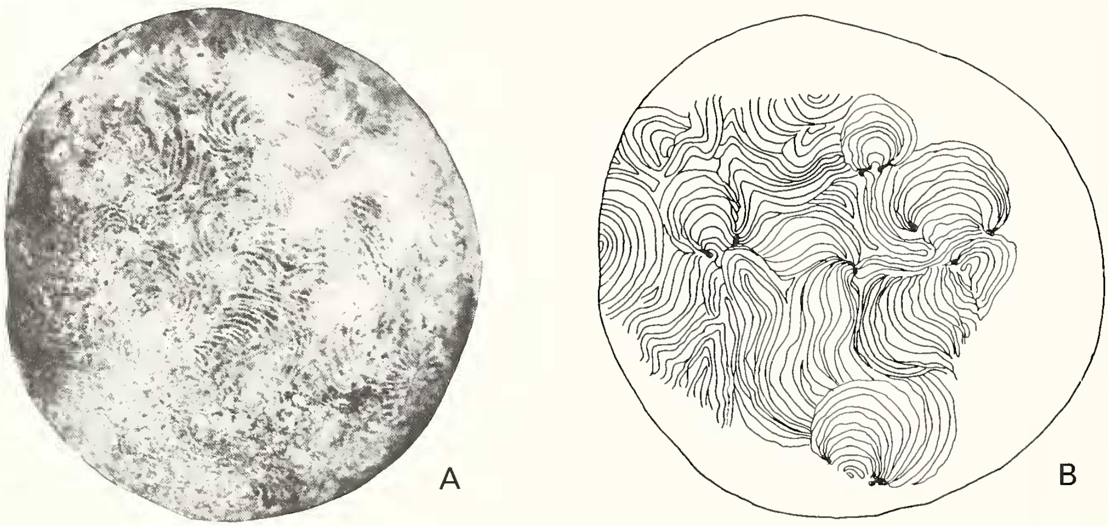
The spiral laminae in the outer part of the mature test are very thin and are easily removed by weathering, thereby exposing the septal filaments and transverse trabeculae (text-fig. 3). The surface of the test is conspicuously marked by septal filaments, the form and arrangement of which show considerable variation. In the early stage of growth the filaments are first radial and then gradually become sigmoidal and wavy. In the adult specimens the poles do not serve as the centre of radiation and the filaments become curved. In smaller lenticular specimens the septal filaments are simple, meandriform. In tests with obtuse margins the filaments become highly sinuous and form complex meandriform patterns. Here, they form small bunches, each made up



TEXT-FIG. 1. Geological map of the area around Lakhpat, Cutch, western India (modified from Sen Gupta 1964). Inset (upper): Map of a part of western India showing location of Lakhpat. Inset (lower): Map of a part of Cutch showing location of Waghapadar, the type locality of *N. obtusus* (Sowerby).



TEXT-FIG. 2. Transverse view outlines of microspheric specimens of *Nummulites obtusus* (Sowerby) from the Middle Eocene of Lakhpat showing variations in the shape of the test, × 3; A, CUGD LN 92; B, CUGD LN 93; C, CUGD LN 94; D, CUGD LN 95; E, CUGD LN 96; F, CUGD LN 97; G, CUGD LN 98.



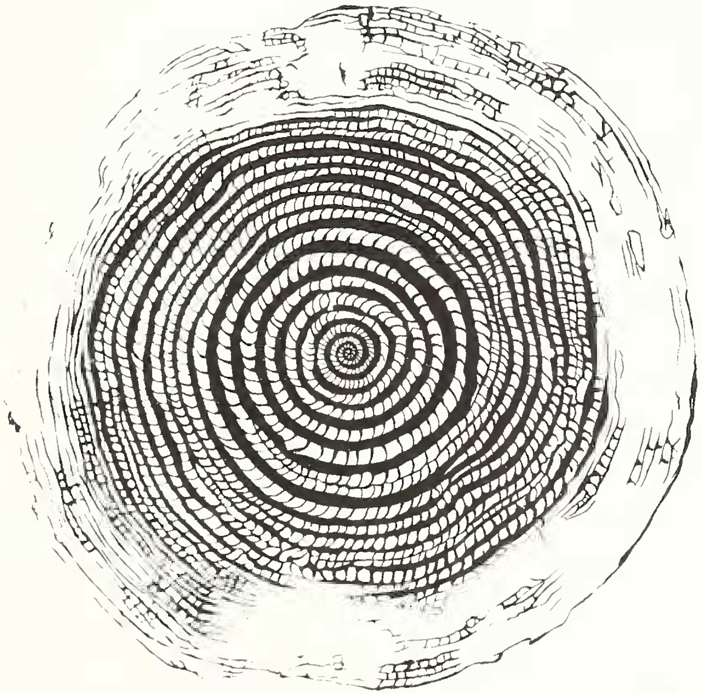
TEXT-FIG. 3. *Nummulites obtusus* (Sowerby) from the Middle Eocene of Lakhpat, Cutch. 3*a*, External view of a microspheric specimen. 3*b*, Drawing showing the complex meandriform septal filaments; CUGD LN 68. Specimen width 16 mm.

of several closely spaced, parallel, meandering filaments arranged around a point producing a fan-shaped outline (text-fig. 3) sometimes resembling finger prints. The septal filaments constituting the different bunches meet at different points forming numerous centres of radiation marked by small white knots on the surface. In thick specimens even the broadly rounded margins are ornamented with bunches of filaments. Thus, this complex form and arrangement of the septal filaments produces an optically striking surface pattern which has been found quite helpful in recognizing *N. obtusus* in Cutch.

Transverse trabeculae are well-developed and vary from fine, minute spinose projections flanking the septal filaments to long thread-like structures extending from one filament to another. In the early growth stage of *N. obtusus* the surface is always ornamented with well-developed polar pustules (Pl. 114, fig. 2). In adult individuals the surface is non-granulate except for minute, scattered protuberances resembling fine papillae on the septal filaments. The occurrence of individuals belonging to different growth stages seems to indicate that the Lakhpat assemblage of *N. obtusus* probably represents a biocoenose.

Internal features. Equatorial section. The most striking feature is the differentiation of the spire into three parts—an inner part consisting of closely spaced regular whorls, a middle part made up of open, irregular whorls with intercalary whorls, and an outer part with very narrow approximated whorls (Pl. 115, fig. 1; text-fig. 4). This differentiation of the spire is best exhibited in large, thick specimens. In smaller specimens the outer part comprises only a few whorls. In mature individuals the middle part covers about three-fifths of the radius of section and the inner and outer parts together cover the rest, the outer part being approximately double the inner part in radius. In a diameter of 18 mm there are about 35 whorls. Of these, 4 occur in the inner part, 16 in the middle part, including 6 intercalary whorls, and 15 in the outer part.

Inner part. Diameter ranges from 2·0 mm to 2·4 mm and includes four to six regular whorls. Marginal cord well-developed, gradually increases in thickness and is regular in its course. Its thickness varies from two-thirds to three-quarters of the height of the whorl cavity. Chambers in the first whorl are not clearly visible, but in subsequent whorls they are radially elongate and rectangular, their height often exceeding three times their length.



TEXT-FIG. 4. Split equatorial section of a microspheric specimen of *Nummulites obtusus* (Sowerby), ×6; CUGD LN 85.

In a diameter of 2·2 mm there are about thirty chambers in the outermost whorl and twenty-five chambers in the preceding whorl. Septa are regularly spaced, well-formed and moderately thick. They are nearly perpendicular to the marginal cord and are virtually straight with a bend at the distal end. The regularity of the whorls with short and high chambers separated by straight, nearly perpendicular septa distinguish this part from the rest of the section.

Middle part. A break in the regularity of the spire and the initiation of change in the character of the chambers and septa mark the beginning of this part. It records the longest and the most significant segment of the ontogeny and the major changes in the essential characters of the equatorial plane occurs in this part. The predominating form of septa and chamber seen here is considered as diagnostic of the species. The generation of intercalary whorls, one of the significant events in the ontogeny of the species, occurs in this part. In the ten split sections examined, the number of intercalary whorls varies from two to six. Thus, the middle part initiated with a simple spire always ends with a multiple spire. The earliest intercalary whorl is generated between the seventh and eighth whorls. When the marginal cord becomes considerably thick there may be insertion of more than one intercalary whorl in quick succession (Plate 115, fig. 1.) as if one of the main functions of the introduction of intercalary whorl is to reduce the thickness of the spiral lamina. The occurrence of intercalary whorls introduces significant change in the rhythm of the growth of the shell.

Prior to the formation of the intercalary whorls the spire is fairly regular and the height of the whorls increases appreciably. The whorl cavity attains its maximum height here. With the insertion of intercalary whorls the major irregularity in the spire sets in and the radial distance between the spiral walls displays marked variation. Rarely, an intercalary whorl pinches out. Here the whorls are more closely spaced than in the early part.

The spiral lamina thickens progressively from the beginning and in the early stage of the middle part attains its maximum thickness making this section conspicuous. With the initiation of intercalary whorls this trend in increase of thickness is arrested and the wall becomes gradually thinner. Often in the process of formation of intercalary whorls the lamina splits into two equal parts. As a rule the thickness of the spiral wall is highly variable in this part. The course of the lamina is also affected. Gently wavy in early whorls, it becomes very irregular in later whorls. The spiral wall generating the intercalary whorl is usually very thin, thread-like in the beginning. It thickens gradually till it attains the thickness of the outer whorl wall. This extremely thin early part of spiral wall generating the intercalary whorl appears to be devoid of a canaliculate marginal cord. Often it produces a faint zigzag outline when the septa on its either side alternate in position.

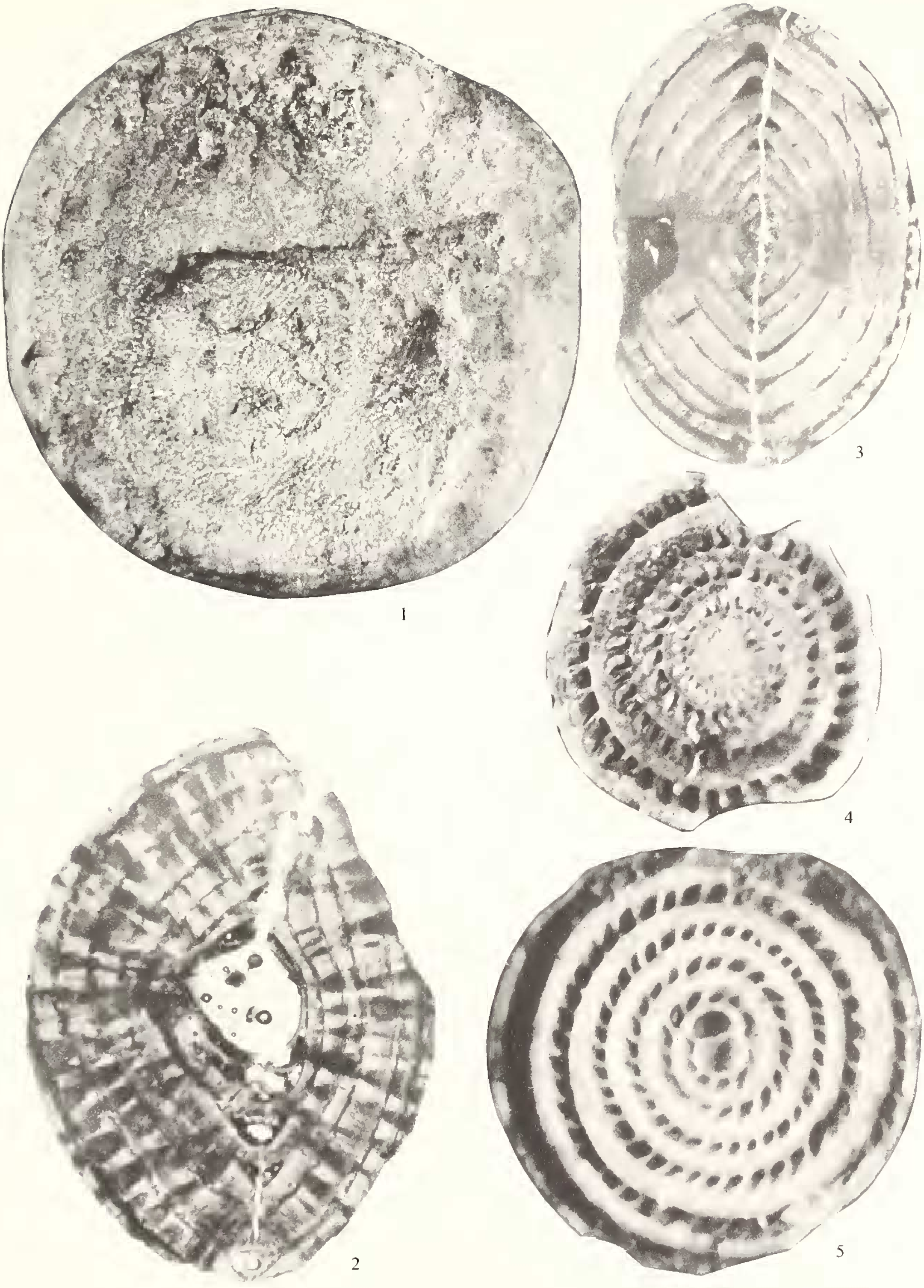
With the initiation of the middle part the septa loose their stiff constant form and become weakly curved and slightly inclined. Usually they are curved backward at their distal end. Septa with curvature in the middle parts also occur. Normally they are slightly but distinctly inclined to the spiral lamina at the base. Strongly inclined septa are confined to the irregular sections of the spire. The rate of introduction of septa is accelerated with the introduction of intercalary whorls. In the early part of such whorls the septa are delicately built.

Chambers are normally higher than long. However, chambers as high as long occur frequently while cavities longer than high also occur but less frequently. This variation results mainly from the introduction of intercalary whorls, and difference in thickness and irregularity in the course of the spiral lamina. Prior to the formation of intercalary whorls the chambers increase gradually in size and cavities one and a half times higher than long occur frequently. Subsequently, the rate of increase slows down and the chambers become distinctly smaller in the later whorls. There are about fifty chambers in one whorl-length of growth just prior to the insertion of intercalary whorl, while in 360° growth of the first intercalary whorl there are about ninety chambers (Plate 115, fig. 1).

EXPLANATION OF PLATE 113

Figs. 1, 2. *Nummulites perforatus* (de Montfort) from the Middle Eocene *Nummulites perforatus* band of Leghia, Cluj. 1. External view of a microspheric specimen showing thin, wavy, irregularly branching septal filaments and granules distributed on and between the filaments, ×3·5; CUGD LN 125. 2. Axial section of a megalospheric specimen showing conspicuously large embryonic apparatus and well-developed pillars, ×17; CUGD LN 158.

Figs. 3–5. *Nummulites obtusus* (Sowerby) from the Middle Eocene of Lakhpat, Cutch. 3. Axial section of a megalospheric specimen showing slightly flattened sides and distinctly developed polar plugs, ×15; CUGD LN 116. 4. Split equatorial section of a microspheric specimen showing the inner part of the spire, X16; CUGD LN 82. 5. Split equatorial section of a megalospheric specimen, ×24; CUGD LN 107.



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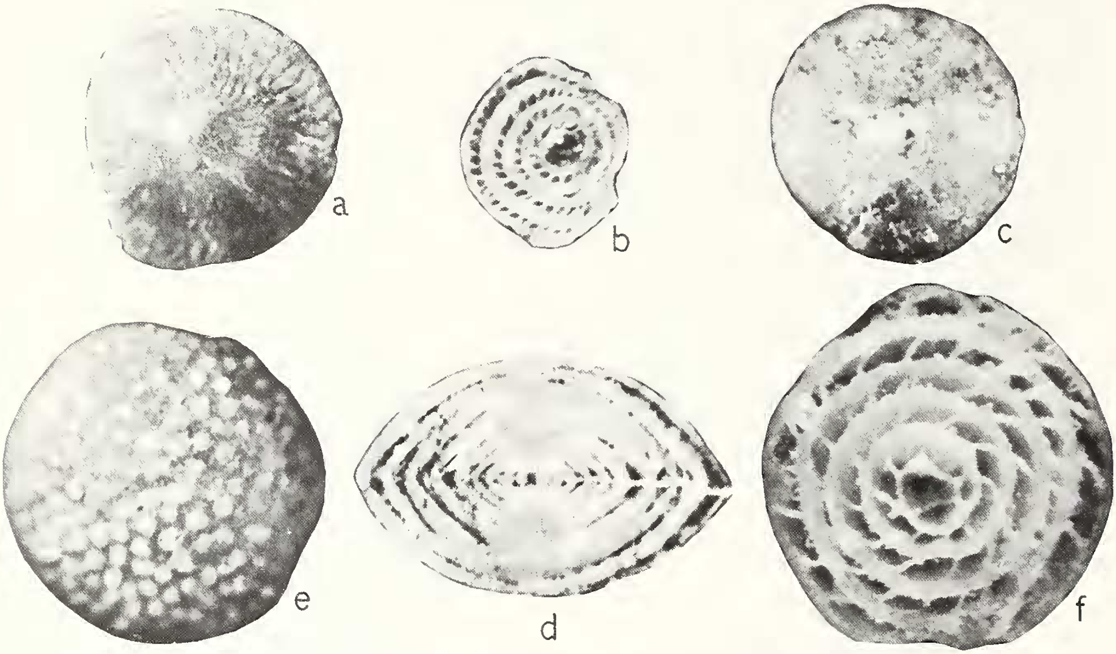
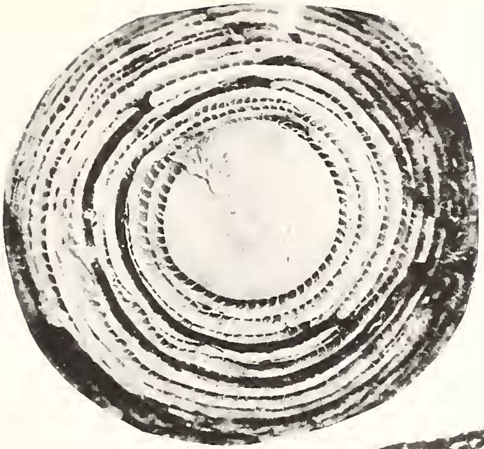
Outer part. The occurrence of very narrow closely spaced whorls between extremely thin spiral wall distinguishes this part, and it is more uniform in appearance than the middle part. The outer part invariably begins with a multiple spire and there is no significant change in the height of the whorls with growth. The spiral wall is gently to moderately wavy and exhibit some variation in thickness. It is usually thinner than the whorl cavity. The marginal cord is not developed, at least in thinner parts of the whorl wall. Septa are very short, rather thin, straight and mostly perpendicular to the spiral lamina. Chambers are characteristically very low, and vary from squarish to long elongated with the length often exceeding twice the height.



TEXT-FIG. 5. *a–d*, *Nummulites obtusus* (Sowerby) from the Middle Eocene of Lakhpat, Cutch. *a*, Microspheric specimen; *b–d*, Megalospheric specimens. *a*, External view of the immature stage showing sigmoidal septal filaments and corded margin, × 7; CUGD LN 72. *b*, Split specimen showing the irregularity of the spire, × 11; CUGD LN 109. *c*, External view showing simple septal filaments and polar pustule, × 9; CUGD LN 104. *d*, Axial section showing distinctly developed polar plugs, × 10; CUGD LN 115. *e*, *f*, *Nummulites perforatus* (de Montfort), megalospheric specimens, from the Middle Eocene *Nummulites perforatus* band of Leghia, Cluj. *e*, External view showing well-developed granules, × 11; CUGD LN 147. *f*, Split specimen showing large embryonic apparatus, × 12; CUGD LN 152.

EXPLANATION OF PLATE 114

Figs. 1–4. *Nummulites obtusus* (Sowerby), microspheric specimens, from the Middle Eocene of Lakhpat, Cutch. 1. Partially split specimen showing the subsequent stage with sigmoidal septal filaments, × 5; CUGD LN 79. Note the absence of a polar pustule. 2. Partially split specimen showing the early stage with distinct polar pustule and radial septal filaments, × 5; CUGD LN 78. 3. Axial section showing the three stages of development, × 10; CUGD LN 95. Polar plugs are restricted to the inner part. 4. Axial section showing marked change in the shape of test in course of the ontogeny, × 10; CUGD LN 96. Note the absence of the marginal cord and the distinctly differentiated equatorial plane in the outer part of the section.



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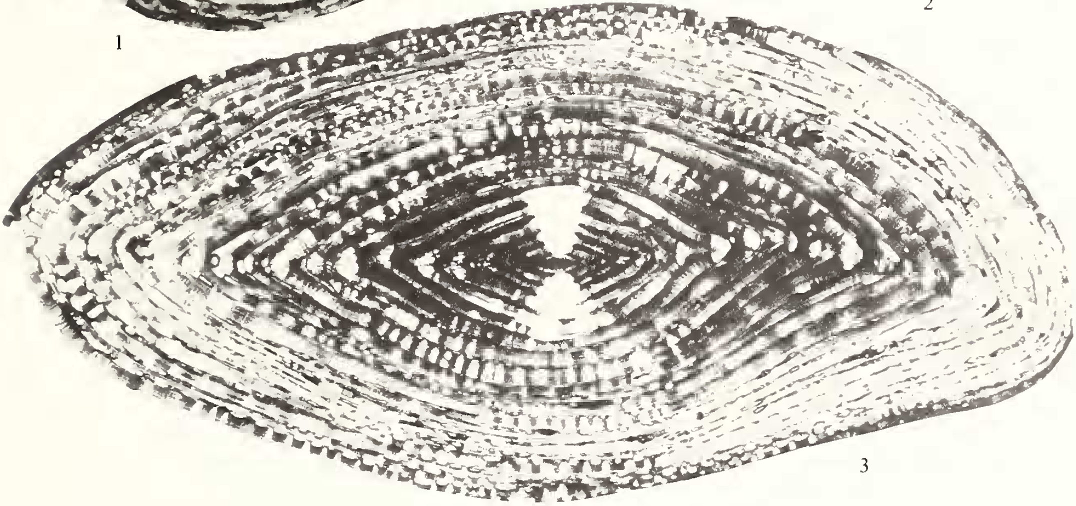

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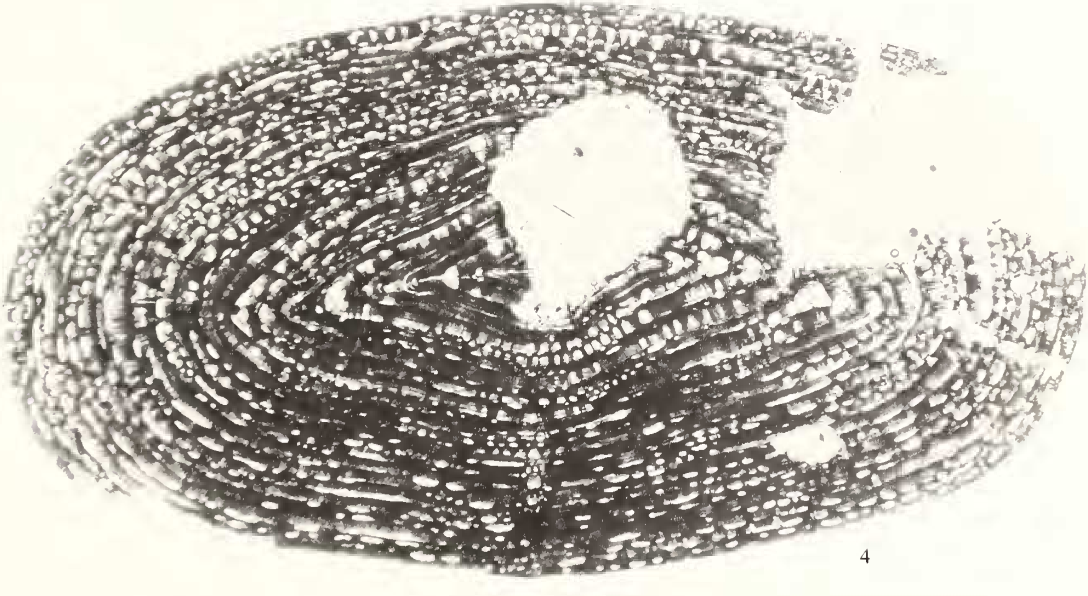

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SAMANTA, *Nummulites*

Axial Section. Three parts distinguished in the equatorial section are also recognizable in the axial section of mature individuals (Plate 114, fig. 4). The inner part is characterized by minute size, equally biconvex to biumbonate outline with angular margin. The equatorial plane is flat, extremely thin and increasing very slowly in thickness. The chambers are low, almost slit-like in early whorls becoming subtriangular in later whorls. Spiral laminae are usually uniform in thickness from the margin to the poles with distinct marginal cord. The alar prolongations are very narrow. Polar plugs are well-developed and occupy about one-third of the diameter of the inner part. Although mostly made up of textural pillars, occasionally they appear to be formed of inflational-textural pillars.

The middle part is equally or unequally biconvex, with subangular to moderately obtuse margin. Asymmetry in the shape of the test is initiated here (Plate 115, fig. 2). The equatorial plane is distinct but becomes curved to gently wavy. The chambers are subtriangular, mostly wider than high, the width exceeding twice the height occasionally. The alar prolongations are rather narrow but distinct, the separating laminae being normally thicker than the cavities. They are subdivided into small, slitlike cavities by short transverse partitions representing sections of meandering filaments. The spiral laminae as well as the marginal cord attain maximum thickness here. In the early whorls the spiral laminae are uniform in thickness from one end to the other, while in later whorls there is considerable variation in their thickness not only from the margin to the pole but also on two sides of the equatorial plane. Lateral splitting of the spiral lamina occurs frequently in the outer whorls producing 'lateral chambers' which are subdivided into small cavities by the meandering filaments. Textural pillars are well-developed in parts of the section with relatively thick spiral laminae (Plate 114, fig. 3). They may be thin or thick, uniform in thickness or wedge-shaped. Although in some individuals there is a tendency to concentrate in the polar region, they are normally distributed throughout the middle part. Usually, these textural pillars are not arranged aligned producing a continuous structure across the whorls.

The outline of the section which changes gradually through the later half of the middle part undergoes marked modification in the outer part producing the characteristic form with flattened polar region and prominently obtuse to bluntly rounded margin (Plate 114, fig. 4). The plano-convex to concavo-convex outline results in this part. The whorl cavity over the sides of the test as well as along the obtuse margins is uniformly subdivided into small, low cavities by sections of septal filaments. As a result the equatorial plane becomes indistinguishable. Here, the formation of a canaliculate marginal cord along the broadly rounded margin of the whorls has also ceased. This loss of the median eqitant chambers and the marginal cord, considered as distinctive features of the genus, is quite significant. The spiral laminae are strikingly reduced in thickness reaching the extreme in outer whorls. In contrast to the earlier part here the height of the cavities exceeds the thickness of the separating laminae. Lateral splitting of the spiral laminae produces 'lateral chambers' which are subdivided into small openings as in the middle part. The spiral laminae are irregularly thickened along the points of attachment with the transverse partitions formed by the septal filaments. These partitions when aligned in successive cavities between the thickened points of the spiral laminae produce the appearance of pillar-like structures (Plate 115, fig. 2). It is the extreme thinness of the spiral laminae which makes them readily discernible here. These are invariably irregular in development and in distribution and extend across up to six or seven whorls only.

Megalospheric generation. Material. Eighteen isolated specimens, five split specimens and four axial sections were examined.

Description. External features. Test small, thick, evenly lenticular to strongly inflated. Margin subangular to obtuse. Polar region tends to be flattened (Plate 113, fig. 3). Surface ornamented with faint to distinctly developed polar pustules occupying up to one-fifth of the test diameter (text-fig. 5). Septal filaments are very thin, gently wavy and closely spaced. Although they form broad sinuosity in their course in some specimens, the meandriform pattern seen in microspheric specimens is not developed. Outside the polar region no granulation could be detected even when decorticated. Test diameter ranges from 2·9 mm to 4·6 mm, thickness from 2·2 mm to 3·0 mm and surface diameter of the polar pustules from 0·6 mm to 1·4 mm.

EXPLANATION OF PLATE 115

Figs. 1, 2. *Nummulites obtusus* (Sowerby), microspheric specimens, from the Middle Eocene of Lakhpat, Cutch. 1. Split specimen showing the three-part spire, ×8; CUGD LN 85. 2. Axial section showing asymmetry of the specimen, curved equatorial plane, small polar plugs confined to the inner part and sections of meandrine septal filaments transversely oriented between the whorl laminae producing the appearance of pillar-like structures, ×8; CUGD LN 93.

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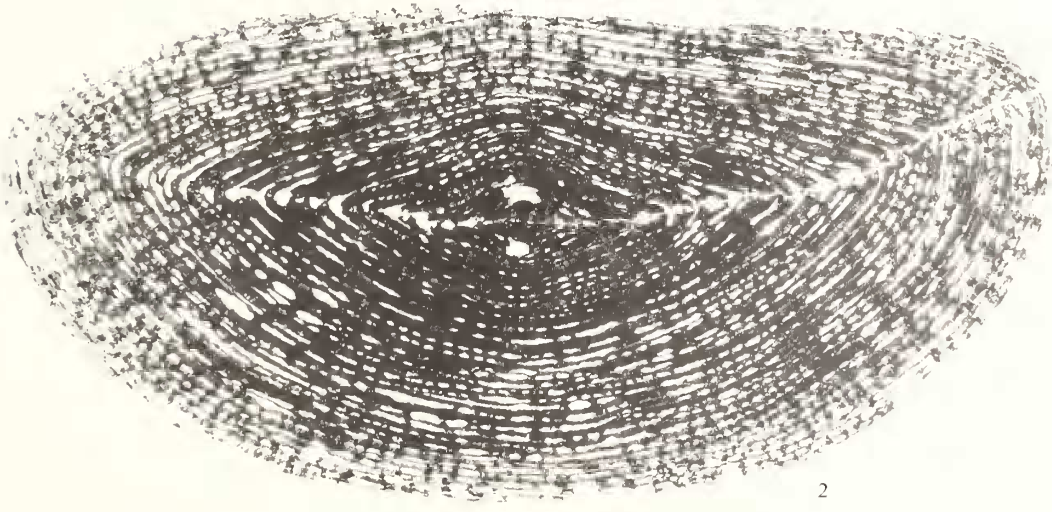

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SAMANTA, *Nummulites*

Internal features. Equatorial section. Embryonic apparatus is moderately large, bilocular, consisting of a subcircular protoconch followed by semicircular to reniform deuteroconch, subequal to distinctly smaller than the protoconch (Plate 113, fig. 5; text-fig. 6). The separating wall is extremely thin, straight to gently convex outwards and provided with a fine opening near the middle which probably served as a passage between them. Both the chambers are slightly compressed along the main axis of the embryonic apparatus. The thin protoconch wall often shows weak angularity along its contact with the septa of the periembryonic chambers. The outer wall of the deuteroconch is provided with an opening near the contact with the separating wall. With their moderately large size, subcircular to semicircular shape and thin wall the two embryonic chambers constitute a unit distinct from the rest of the section. The internal diameters of the protoconch range from 0·2 mm × 0·31 mm to 0·25 mm × 0·38 mm and of the deuteroconch from 0·17 mm × 0·31 mm to 0·15 mm × 0·37 mm. The distance across both chambers ranges from 0·42 mm to 0·45 mm. The separating wall is about 0·05 mm thick.

Spire simple, usually regular, with about five and a half whorls in a radius of 1·5 mm. Marginal cord is well developed, thick, and increases gradually in thickness except in the outermost whorl where it is invariably thinner than the early formed part. In the early whorls it appears to be nearly as thick as the whorl cavity.

The first nepionic chamber differs from the deuteroconch in being much smaller and low, somewhat elongated in shape. Subsequently, the chambers increase gradually in size and are normally higher than long. However, chambers equal in height and length and distinctly longer than high also occur owing to variation in the spacing of the septa. In the outermost whorl chambers longer than high usually predominate. There are 12 chambers in the first whorl, 19 in the second, 33 in the third, and 36 in the fourth (Plate 113, fig. 5). The septa are short and thick and are slightly inclined to the marginal cord. The slowly opening whorls with thick marginal cord and closely spaced septa give a compact appearance to the equatorial section.

TEXT-FIG. 6. Split equatorial section of a megalospheric specimen of *Nummulites obtusus* (Sowerby), × 12; CUGD LN 107.

Axial section. Inflated biconvex with subangular to obtuse margin. There is no appreciable change in the shape of the test with growth (Plate 113, fig. 3). The subcircular protoconch is followed by reniform deuteroconch. The chambers are triangular, distinctly wider than high, the width often becoming nearly twice the height. The alar prolongations, narrow in the early whorls, become appreciably wider in later whorls. The spiral laminae are thick there but thinner at the margins. They are considerably thicker than the alar prolongations. Polar plugs made up of textural pillars are distinctly developed and extend up to the surface.

Remarks. Sowerby's 1840 Fig. 14*a* is not included in the synonymy since it clearly depicts a granulate species such as *N. acutus* (Sowerby) rather than the smooth *N. obtusus*. As mentioned earlier, Sowerby did not describe his new species properly, but merely noted, in the plate explanations, those features which distinguished it from others in his material. His illustrations were too small to show the essential features clearly. D'Archiac and Haime (1853) provided the first well-illustrated systematic account of this species although they did not mention the provenance of their figured specimens which, however, agree closely with those described here from the type area. Prior to the publication of Sen Gupta (1965) these were the only satisfactory illustrations. Both Sowerby and d'Archiac and Haime examined only the microspheric generation. Carter (1853) pointed out that young individuals from Sind were characterized by simple, sigmoidal filaments, and his identifications were accepted by d'Archiac and Haime (1853, pp. 342, 343). Later, Carter (1861, p. 371) observed that a closer examination of the specimens described in his earlier paper (1853) revealed the existence of 'puncta' on the surface which was, however, virtually devoid of granulation.

Blanford (1879) reported that *N. obtusus* was a commonly occurring fossil in Sind and an important component of the fauna of the Khirthar Group. Although specimens sent to Professor

Rupert Jones were returned marked *N. perforata* var. *obtusa* (Blanford, *op. cit*., p. 10), both Blanford (1879) and Medlicott and Blanford (1879) continued to refer their material to *N. obtusus*. Vredenberg (1906) referred to his specimens as *N. gizehensis* var. *obtusus*, but without giving any reason. Davies (1940), in describing and illustrating *N. obtusus* from Kohat, placed (p. 222) part of Vredenburg's specimens in synonymy. Although Sen Gupta (1965) illustrated both the generations from Cutch, his figures were not adequately enlarged to show the diagnostic characters clearly.

Examination of other records of *N. obtusus* from the region between southern Europe and eastern India indicates that most really refer to different species. Schaub (1962*a*) showed that the Italian specimens described by Danielli (1915) were different; those described by Bozorgnia and Kalantari (1965) from Iran are pillared and have chambers that are longer than high, together with strongly inclined flexuous septa. Nuttall's (1926) three figured specimens from Baluchistan are pillared and have different septal filaments (those from Sind were unfigured). The specimens described by Nagappa (1959) from Sind have more inclined, curved septa, and chambers that tend to be longer than high; those from Meghalaya, eastern India, differ in over-all shape and in characters seen in the equatorial section. Nagappa's remarks (*op. cit*., p. 164) indicate that his concept of *N. obtusus* was different from mine.

N. obtusus (Sowerby) is one of the most distinctive species of the genus recorded from the Indian region and is readily recognized even in the field. In Lakhpat material the microspheric specimens are more common than the megalospheric individuals and exhibit variations in both external and internal features. In course of the ontogeny the microspheric generation undergoes marked modifications so much so that in the absence of a detailed examination of the internal features of the mature individuals it becomes difficult to correlate the specimens representing the different growth stages.

The morphological difference between the mature microspheric specimens and the megalospheric individuals of *N. obtusus* is also notable. With its much smaller size, distinctly developed polar pustules and simpler septal filaments, the megalospheric form differs markedly from the microspheric form making it difficult to correlate them. Internally, also, there is significant difference between the two generations. The tripartite subdivision of the microspheric spire is absent here. The moderately large megalospheric embryonic apparatus seems to correspond to the inner part of the microspheric spire. The postembryonic growth of the megalospheric form, characterized by a simple spire, corresponds to the early stage of the middle part of microspheric spire formed prior to the insertion of intercalary whorls. The form of the septa and the chambers occurring in this inner section of the middle part is closely comparable to that of the megalospheric form. Except for the tendency of the last whorl to be narrower than the preceding one, the outer part of the microspheric spire is not represented in the megalospheric individuals. Although internally different the megalospheric specimens bear some resemblance to the young individuals of the microspheric generation in possessing polar pustules and simpler septal filaments.

The megalospheric embryonic apparatus is of the 'isolepidine type' as defined by Bieda (1963, p. 59). Conforming to Bieda's definition, in *N. obtusus* the shape of the two chambers together often resembles that of figure 8. The occurrence of this type of embryonic apparatus in *N. obtusus* is noteworthy since in most of the large, evolved species of the genus occurring in the Middle Eocene the megalospheric embryonic apparatus is of the 'anisolepidine type' of Bieda where the protoconch is much larger than the deuteroconch.

The earliest reference to the three-fold subdivision of microspheric spire in *Nummulites* was made by D'Archiac and Haime (1853). Since then other workers have illustrated this in a number of Middle Eocene spcies occurring in different areas including the Indian region. The development of closely spaced narrow whorls in the outer part of the spire attracted the special attention of some of these workers who attempted to explain the cause of their formation. A group of workers regarded this as an irregularity of the spire caused essentially by the changes in the external environment. Thus, Said (1950, p. 30) in a study of *Nummulites gizehensis* (Forskål) suggested that the tightening of the outer whorls was seasonal and caused by a limited supply of food during the winter season. His postulation was based on the assumption that the observation made by Myers (1943) during his experimental work on Recent larger foraminifera in the Pacific that 'chambers added during seasons of limited food supply became short and narrow compared with those when food was abundant' was also applicable to *Nummulites gizehensis*.

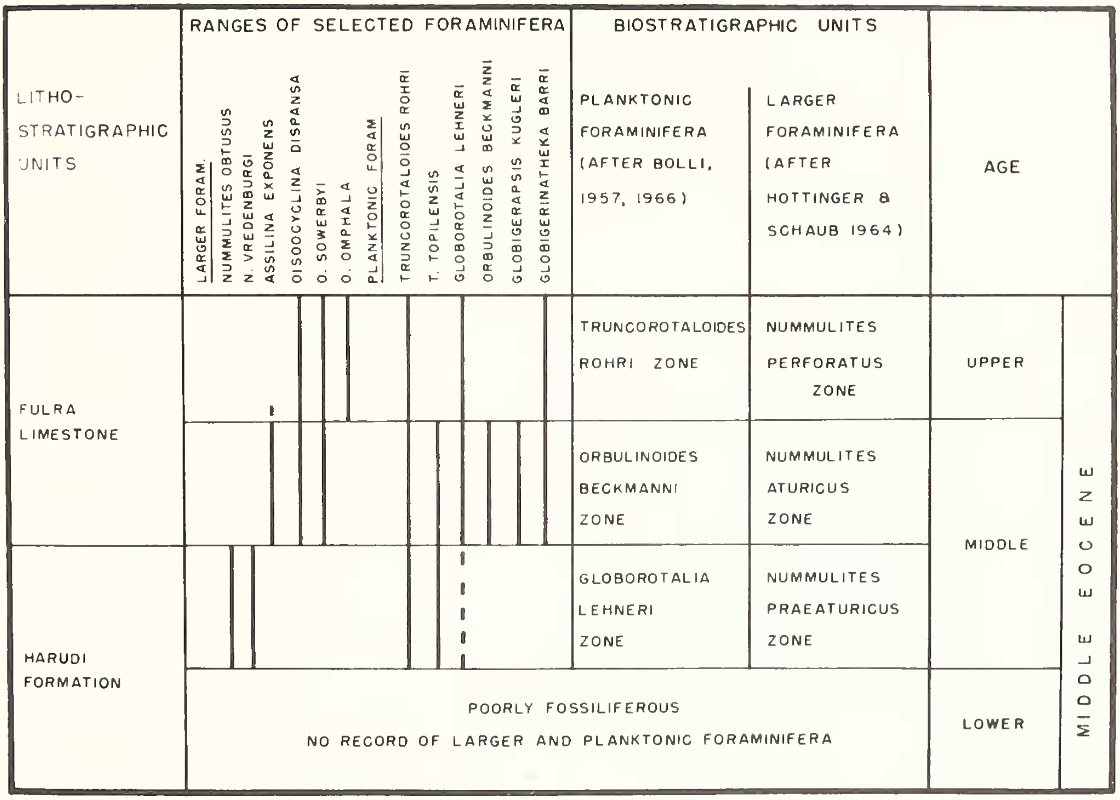
On the other hand, Schaub (1962*b*, 1963) demonstrated the gradual differentiation of the microspheric spire with time into three well-defined sections in more than one lineage occurring between the early Lower Eocene and late Middle Eocene, and established that this development constitutes one of the most important evolutionary trends in the genus. According to him the middle part represents the main segment of the spire and shows the distinctive features of the species while the inner part which is most conservative exhibits the characters of the ancestral species and is thus very useful in deciphering the phylogeny of the group. Thus, judging from the characteristics of its inner part, Sowerby's species seems to have been derived from a non-granulate ancestral stock distinguished by a regular spire with high, short chambers between more or less straight, nearly vertical, closely spaced septa. This ancestral form bears a resemblance to *Nummulites deserti* de la Harpe (1883) originally described from the Upper Palaeocene of Egypt and later recorded from the Upper Palaeocene of several other localities in the Alpine–Mediterranean region. *Nummulites wadiai* Davies, described from the Upper Palaeocene of Pakistan (Davies 1927), seems to have served as the ancestral stock for several species of *Nummulites* occurring in the India-Pakistan region. However, further information on the external and internal features of both the generations of Davies' species is essential. From the illustration of its megalospheric generation the surface of *N. wadiai* appears to be granulated and it was treated as related to the *N. solitarius–N. burdigalensis* lineage (Schaub, 1951, pp. 76, 99).

According to Schaub in the course of the evolution the outer part of the spire increases in size at the expense of the middle part and attains its maximum width in the youngest representative of the lineage. Here, in *N. obtusus* (Sowerby) the development of this outer part appears to be connected with the occurrence of intercalary whorls. As mentioned earlier the thickness of the spiral wall and the height of the whorls are strikingly reduced with the introduction of the intercalary whorls. It seems as if this continued process of splitting up the spiral wall with the insertion of successive intercalary whorls ultimately results in the formation of the outer part with the characteristic narrow whorls between thin spiral walls.

The outer part of the spire exhibits changes in several important characters. In the broadly rounded margin the canaliculate marginal cord is not developed and the recognition of a distinct equatorial plane is not possible. As described in case of *Miscellanea meandrina* (Carter) (Smout 1954, p. 74, pl. 10, figs. 1*a*, *b*), here in *Nummulites obtusus* also, the meandering septal filaments cover the obtuse margin of the whorls and in axial section the entire cavity between the two whorl walls is uniformly subdivided in the two sides and in the margins. Thus, the structure of the test appears to be modified to such an extent that on the basis of the examination of the outer part alone it becomes difficult to identify the specimen generically.

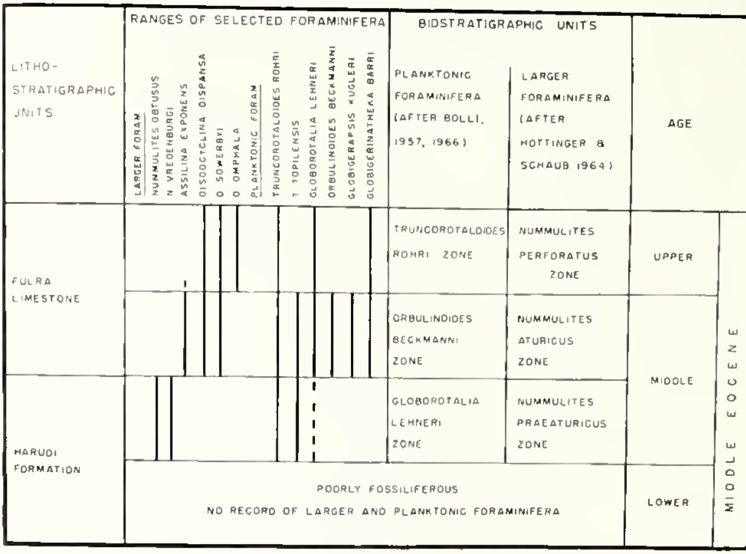
Although the generations of intercalary whorls in *Nummulites* significantly modifies the appearance of the equatorial plane, little attention has been paid to this in the literature. Yet the same feature in the Rotaliidae has been used as a basis for erecting two genera (*Dictyoconoides* and *Dictyokathina*) despite the fact that other important structural modifications found in *Nummulites* are absent. Smout (1954) observed that in these rotaliid genera the spiral lamina generating the intercalary whorls shows little variation in thickness, and that notable change in the shape and size of the chambers in these whorls is lacking.

Distribution. Although reported from different parts of the Tethyan region, this investigation indicates that *N. obtusus* is essentially restricted to Cutch in western India and the adjoining Sind-Baluchistan-N.W.F. Province of Pakistan (see also d'Archiac and Haime, 1853). In Cutch *N. obtusus* is restricted to the upper part of the Harudi Formation. Although in the Lakhpat area there is a break in the succession between the Harudi Formation and the overlying Fulra Limestone, in other localities the Harudi Formation is conformably overlain by the Fulra Limestone. The lower part of the Harudi Formation is poorly fossiliferous. The stratigraphic distribution of selected larger and



TEXT-FIG. 7. Stratigraphic range of *Nummulites obtusus* (Sowerby) in Cutch, western India. Based on personal observations except for the planktons in the upper part of the Harudi Formation.

planktonic foraminifera in the Harudi Formation and Fulra Limestone is shown in text-fig. 7. The reported occurrence of *O. beckmanni* in the Harudi Formation (Biswas and Raju, 1971, 1973) is unreliable and needs checking (Biswas, oral communication). The proposed correlation and age determination are essentially based on planktonic foraminiferal evidence. As pointed out by Samanta (1970, p. 189) 'a direct and precise correlation of the present sequence with the classic succession in Europe on the basis of larger foraminifera' is not possible because most of the larger foraminifera occurring in the Middle Eocene of Cutch are not known to occur in European localities. As shown in text-fig. 7 the upper part of the Harudi Formation with *N. obtusus* is correlatable with the *Globorotalia lehneri* Zone of Bolli (1957, 1966). On the strength of this correlation the *N. obtusus*-bearing horizon in Cutch is provisionally treated as equivalent to the *Nummulites praeaturicus* Zone of Schaub. Thus, in the type area of Cutch *N. obtusus* is middle Middle Eocene in age. Nagappa's (1959, p. 173, chart 3) attempt to show *N. obtusus*/*N. uroniensis* ranging from lower part of the Middle Eocene to almost the top of the Upper Eocene is misleading since his concept of *N. obtusus* is unclear in the absence of observations or illustrations of specimens from the type area. Furthermore, the ranges (all Middle Eocene) given in his various tables conflict with the total range shown on chart 3.



TEXT-FIG. 7. Stratigraphic range of *Nummulites obtusus* (Sowerby) in Cutch, western India. Based on personal observations except for the planktons in the upper part of the Harudi Formation.

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Nummulites perforatus (de Montfort)

Plate 113, figs. 1, 2; Plate 116, figs. 1, 2

1808 *Egeon perforatus* de Montfort, pp. 166, 167, 2 text-figs.
1853 *Nummulites perforata* d'Orbigny; d'Archiac and Haime, pp. 115–120, pl. 5, figs. 1–1*g*.
1853 *Nummulites lucasana* Defrance; d'Archiac and Haime, pp. 124–127, pl. 7, figs. 5–5*c*.
1962*b* *Nummulites perforatus* (de Montfort); Schaub, p. 327, fig. 7.
1963 *Nummulites perforatus* (de Montfort); Schaub, pp. 291, 294, fig. 2.
1968 *Nummulites perforatus* (de Montfort); Bombiţâ and Moisescu, pp. 700–703, pl. 2, figs. 1, 13.
1976 *Nummulites perforatus* (de Montfort); Rahaghi and Schaub, p. 775, pl. 4, fig. 5; pl. 5, figs. 1*a*, *b*.

Microspheric generation. Material. Ten isolated specimens, five split specimens and three axial sections were examined.

Description. External features. Test large, inflated lenticular to subglobose with an obtuse, broadly rounded margin. Polar region usually broadly convex in adult specimens (Plate 116, fig. 2). Individuals with unequally biconvex, concavo-convex and elliptical transverse outlines occur. Septal filaments fine, thread-like, irregular, wavy and radiate from several centres. They often branch irregularly making it difficult to follow their course. Surface ornamented with fine, subcircular, elongate or irregular granules varying little in size from polar region to the periphery. They are irregularly spaced, and occur on and between the filaments (Plate 113, fig. 1). When closely spaced the granules tend to obscure the filaments. In globose individuals the broadly rounded margin is also ornamented with septal filaments and granules. Test diameter ranges from 21·5 mm to 29·2 mm; thickness from 9·4 mm to 12·6 mm; surface diameter of granules from 0·18 mm to 0·3 mm.

Internal features. Equatorial section. Characterized by a tripartite spire (Plate 116, fig. 1; text-fig. 8), the inner part of which occupies up to about one-sixth of the radius, the remainder being almost equally shared by the middle and outer parts. The outer part often occupies more than half the radius of the test.

The inner part comprises a simple, tight, regular spire. The marginal cord is regular and considerably thinner than the whorl cavity. The chambers are nearly as high as long and increase gradually in size. The septa are thin, slightly inclined and weakly arched at their distal ends; they gradually become more widely spaced as growth proceeds.

The middle part is characterized by the occurrence of intercalary whorls which, although first appearing halfway through this division, are most numerous in the transitional region between the middle and outer sections. In the middle part, the spire becomes wider and the marginal cord is considerably thickened. In the outer whorls of this part the marginal cord tends to be irregular and often appears thicker than the chamber cavity in places; in the inner whorls it is appreciably thinner than the whorl cavity. The chambers are considerably longer than high. From about twice as long as high in the inner whorls they become three to four times longer than high in the outer whorls. The septa are long, inclined at the base and are distinctly curved, their degree of inclination increasing from the inner to the outer whorls. They are thick at the proximal end and gradually become thinner towards the distal end. In the low chambers of the outer whorls the distal part of the septa is strongly curved backward and run for a distance nearly sub-parallel to the marginal cord. In general the spacing of the septa becomes appreciably wider with growth in this part.

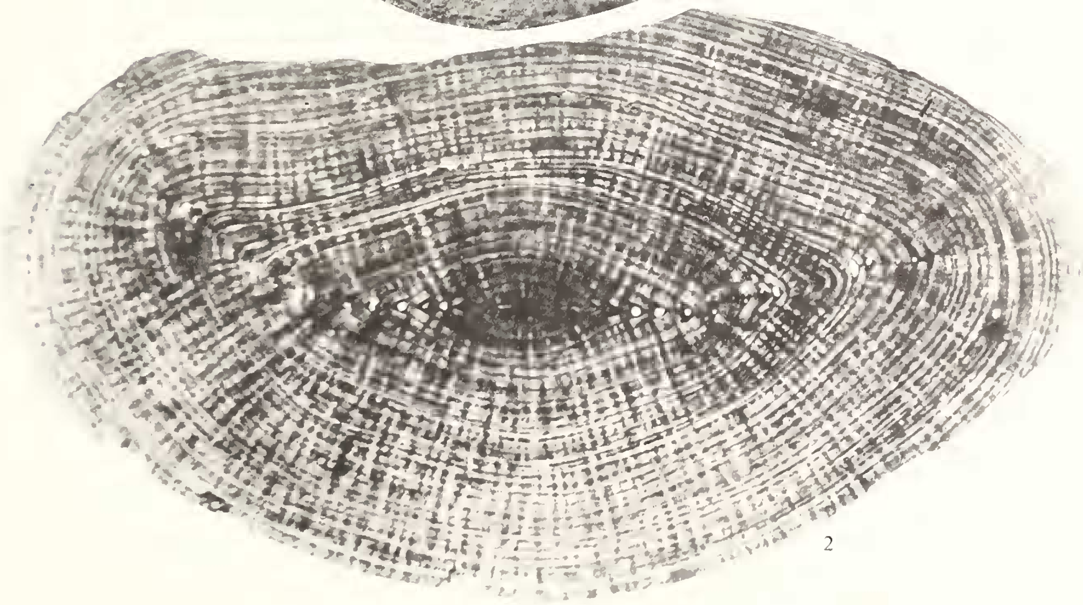
The outer part of the spire comprises tight, narrow whorls between thin spiral lamina and very low, long chambers. In places the height of the whorl equals the thickness of the spiral wall. The septa are inclined, very short, and irregularly spaced.

Axial section. The inner part with equally biconvex outline and angular margin is followed by an inflated, biconvex portion with a subangular to obtuse margin; finally, the test becomes strongly inflated with a broad rounded margin (Plate 116, fig. 2). Unequal biconvexity of the sides although initiated in the middle part

EXPLANATION OF PLATE 116

Figs. 1, 2. *Nummulites perforatus* (de Montfort), microspheric specimens, from the Middle Eocene *Nummulites perforatus* band of Leghia, Cluj. 1. Split specimen showing the three-part spire, ×6; CUGD LN 132. 2. Axial section showing distinctly developed pillars distributed throughout the section, ×6; CUGD LN 142.

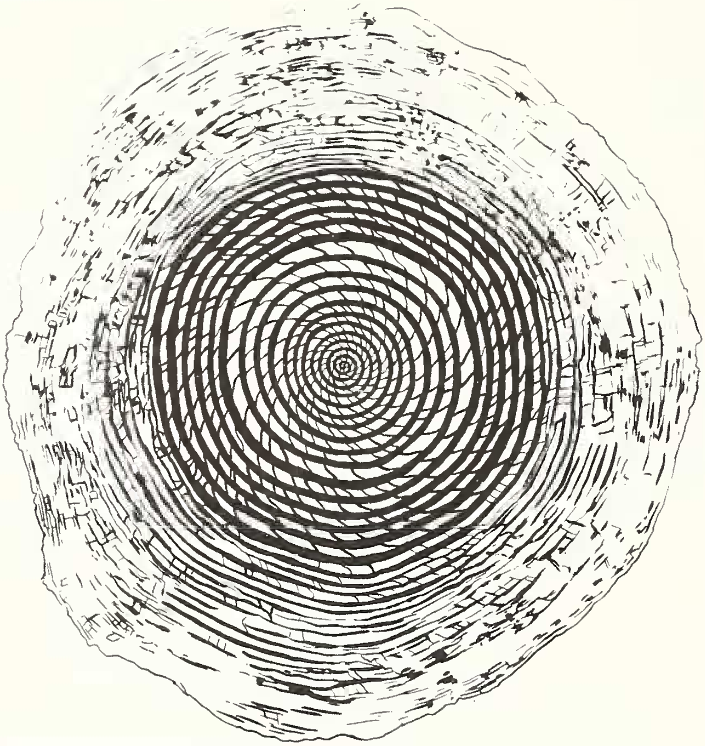
1



2

SAMANTA, *Nummulites*

becomes pronounced only in the outer part. The equatorial plane is narrow and flat in the inner part becoming gradually wider and curved with growth in the middle part. In the terminal part an equatorial plane is not discernible. The chambers are subtriangular, higher than wide in the early whorls, gradually becoming wider than high in later whorls. The marginal cord which is distinctly developed in the middle and inner parts is invariably lacking in the terminal part. There is frequent splitting up of the spiral lamina on either side of the section, and at the margin they tend to be thinner. The alar prolongations are usually narrower than the spiral lamina and are subdivided into small cavities by partitions formed of sections of septal filaments. Pillars are numerous, closely spaced, variable in thickness, and distributed throughout the test. In adult individuals even the broadly rounded margins are pillared. The pillars usually bifurcate once or twice before reaching the surface forming distinct granules.



TEXT-FIG. 8. Split equatorial section of a microspheric specimen of *Nummulites perforatus* (de Montfort), ×4·5; CUGD LN 132.

Megalospheric generation. Material. Twenty isolated specimens, thirty split specimens and two axial sections were examined.

Description. External features. Test small, lenticular to strongly inflated, globose; often unequally biconvex. Margin weakly angular to obtuse. Surface covered with coarse irregular granules (text-fig. 5). Septal filaments thread-like, irregular, not readily discernible in the coarsely granulated polar region. Most granules situated on the filaments. Test diameter ranges from 3·9 mm to 5·2 mm; thickness from 2·2 mm to 3·7 mm; surface diameter of granules from 0·15 mm to 0·3 mm.

Internal features. Equatorial section. Large, bilocular embryonic apparatus, consisting of a large, usually angular protoconch is followed by a more or less subtriangular to cap-like deuteroconch about one-half to one-third of the protoconch in size (text-fig. 5). The separating wall is delicate and gently curved. The outer wall of the protoconch is also very thin and develops weak angularity at its contacts with the septa of the periembryonic chambers. The internal diameters of the protoconch ranges from 0·56 mm × 0·66 mm to 0·64 mm × 0·80 mm and of the deuteroconch from 0·28 mm × 0·48 mm to 0·32 mm × 0·58 mm.

Spire simple, usually regular, with about five whorls in a radius of 2·3 mm. Embryonic apparatus is followed directly by open whorls increasing only slightly in height in the inner part and not all in the out part. The marginal cord is well-developed, regular and increases very slowly in thickness except in the outer whorls where it tends to be thinner. In the inner whorls the height of the whorl cavity is about three times the thickness of the marginal cord.

The first nepionic chamber is small and variable in outline. It is followed by elongate chambers between long, strongly inclined and curved septa. Chambers are usually longer than high, often becoming twice as long as high and increase slowly in size. There are about 9 chambers in the first whorl, 12 in the second, 16 in the third, and 22 in the fourth (text-figs. 5, 9).

Axial section. Protoconch large and subcircular; deuteroconch much smaller and crescentic. Post-embryonic chambers are small, subtriangular and usually wider than high. The spiral laminae are thick with a tendency to be thinner at the margin. They are several times wider than the alar prolongations. Pillars are conspicuously developed over the whole test and are made up of thick wedge-shaped structures (Plate 113, fig. 2). Their surface diameters range from 0·15 mm to 0·3 mm.

Remarks. The original account of *Egeon perforatus* (Montfort, 1808), supported by a generalized drawing showing only the external ornamentation of a specimen, was not adequate enough to recognize it even generically. Later authors did not redescribe or illustrate the original material showing the distinctive features of the species. Owing to the inadequate description of the original material, Douvillé (1917) attempted to suppress the name *N. perforatus* and use *N. aturicus* Joly and Leymerie instead. D'Archiac and Haime (1853) provided the first detailed account of *N. perforatus* based on microspheric individuals from different localities including the type area. They described the megalospheric generation as *N. lucasanus* Defrance (see Schaub, 1960, p. 444). Individuals identified as varieties of *N. perforatus* by them are here regarded as different species. Recently, Schaub carried out systematic examination of *N. perforatus* from different parts of the Tethyan region including the type locality and confirmed that morphologically and stratigraphically it is one of the most distinctive species of the genus. Schaub (1962*b*; 1963) and Bombiţâ and co-workers (1968, 1975) figured topotypes showing the characteristics of *N. perforatus*.

There is difference of opinion regarding the range of variation of *N. perforatus*. D'Archiac and Haime (1853) recognized three new varieties and de la Harpe (1881–1883) identified several more. Recent studies by Schaub and his coworkers have shown that most of these are specifically distinct from *N. perforatus* s.s. Boussac (1911) included under *N. perforatus* several distinct species without providing any supporting evidence. Commenting on Boussac's concept of the species, Hottinger and Schaub (1964*b*, p. 627) rightly observed, 'Il appela «*Nummulites perforatus*» des formes de tailles, de dimensions et d'âges tout à fait différents'. Boussac's publication confused later authors about the identity of Montfort's species. This is particularly significant because most reports of *N. perforatus* by later workers on India and adjacent regions were essentially based on Boussac's concept and are thus not reliable. *N. aturicus* Joly and Leymerie, *N. crassus* Baubée and *N. uranensis* (de la Harpe), regarded as synonyms of *N. perforatus* by some workers (Cotter, 1914; Nuttall, 1926; Sen Gupta, 1965), are morphologically and stratigraphically distinct from Montfort's species (see Schaub, 1963).

Distribution. N. perforatus has been reported from Spain and Morocco in the west to Indonesia in the east. A number of these reports, however, include forms that are specifically distinct. This species occurs commonly in the European part of the Tethys and has been described from successions in Transylvania, Italy, the Alps and the areas bordering the Pyrenees (d'Archiac and Haime, 1853; Hottinger and Schaub, 1960, 1964*a*). Its reported occurrence in North Africa needs to be documented by good illustrations. In the Middle East the only authentic record of *N. perforatus* is from Iran (Rahaghi and Schaub, 1976). The form identified as *N. perforatus* var. by Grimsdale (1952) from Iraq is different from Montfort's species in external and internal features. Although there are numerous references (Carter, 1861; Vredenburg, 1906; Nuttall, 1926; Eames, 1952) to the occurrence of *N. perforatus* in different parts of Pakistan, in the majority of these publications the species has been listed only and an adequate description and illustration of the Pakistani specimens showing the diagnostic features of the species to justify the identification is still lacking. The specimens from the

TABLE 2. Essential morphological features of the microspheric and megalospheric generations of *N. obtusus* (Sowerby) and *N. perforatus* (de Montfort)

Morphological features / Species	External			Internal				
	Size and Shape	Septal Filaments	Granulation/ Polar pustule	Megalospheric embryonic chambers	Spire	Chamber	Septa	Pillar/Polar plug
N. obtusus (A)	Inflated lenticular to subglobose; small	Sigmoidal to broadly sinuous	Polar pustules only	'Isolepidine' type; protoconch moderately large, subcircular	Simple	Usually higher than long; thirty-three chambers in the third whorl	Slightly inclined, gently curved	Only polar plug
N. perforatus (A)	Inflated lenticular to subglobose; small	Irregular in course	Granules covering the surface from pole to the periphery	'Anisolepidine' type; protoconch conspicuously large, usually angular in outline	Simple	Usually longer than high; sixteen chambers in the third whorl	Strongly inclined, curved	Well-developed pillars distributed throughout the axial section
N. obtusus (B)	Thick, lenticular to nearly globose; medium to large	Complex meandriform	Surface devoid of readily discernible granules		Tripartite; becomes multiple in the middle part	In the middle part of the spire usually higher than long	In the middle part slightly inclined, gently curved	Buried polar plugs in the inner part; textural pillars in middle part; weakly developed short transverse structures in the outer part
N. perforatus (B)	Thick, lenticular to subglobose; large	Irregular and wavy in course; anastomosing	Surface from pole to the periphery covered with granules		Tripartite; becomes multiple in the middle part	In middle part two to three times longer than high	In the middle part strongly inclined, distinctly curved	Moderately developed pillars distributed throughout the axial section

Garo Hills, eastern India provisionally assigned to *N. perforatus* by the writer (1968) are specifically distinct from the typotypes of Montfort's species. All reports of *N. perforatus* from western India refer to *N. obtusus* (Sowerby). Believing that *N. perforatus* and *N. obtusus* were not distinguishable, Sen Gupta (1964, 1965) and other workers used the name *N. perforatus* to record the occurrence of *N. obtusus* (Sowerby) in western India. Similarly, the report of *N. perforatus* in Indonesia by Doornink (1932) actually refers to the occurrence of *Nummulites javanus* Verbeek var. α and β. Doornink's observation that *N. perforatus* (de Montfort), *N. obtusus* (Sowerby), and *N. javanus* Verbeek var. α and β are not specifically distinguishable was not accepted by Caudri (1934), and later workers (Adams and Haak, 1962; Adams, 1970) have retained *N. javanus* as a separate species. Thus, there appears to be no reliable record of *N. perforatus* s.s. in the region between Pakistan and Indonesia.

In its type locality *N. perforatus* is restricted to a 3 m thick band which has been dated as Upper Lutetian (= Biarritzian) by Bombiţâ *et al.* (1975). Schaub (1963) observed that *N. perforatus* s.s. is typically restricted to the late Middle Eocene (= Biarritzian) in different localities in the Tethyan belt and used it as the nominative taxon of the highest Middle Eocene nummulites zone. As shown in text-fig. 7, this zone is tentatively correlatable with the highest Middle Eocene planktonic foraminiferal zone, the *Truncorotaloides rohri* Zone (Herb, 1962; Samanta, 1970).

SUMMARY

The essential morphological features of the two species are summarized in Table 2. Microspheric and megalospheric generations of *N. obtusus* can readily be distinguished from those of *N. perforatus* externally, in equatorial section and in axial section. Externally, *N. obtusus* differs from *N. perforatus* in having a non-granulate surface. Internally, they differ in the character of the embryonic chambers, equatorial chambers and septa. The occurrence of pillars in *N. perforatus* distinguish them in axial sections. The microspheric forms resemble each other only in external shape and the tripartite spire with well-developed terminal part. The megalospheric generations are more markedly different. Ontogenetically, also, the two species differ from each other. The early growth stage of *N. obtusus* is provided with polar pustules only, while in *N. perforatus* it is always granulate. The stratigraphical ranges of the two species differ: *N. perforatus* is restricted to the late Middle Eocene *N. perforatus* Zone, while *N. obtusus* is known to occur in the middle Middle Eocene *N. praeaturicus* Zone. *N. obtusus* is restricted to the India–Pakistan region, while as yet there is no authentic record of *N. perforatus* in this area.

Schaub (1962*a*) suggested that *N. obtusus* might be related to the tightly coiled branch of the *N. burdigalensis-perforatus* Group. According to Schaub (1951) and Herb (1965) that group is characterized by a thick lenticular test with strong pillars on and between the septal filaments. Although *N. obtusus* possesses a thick lenticular test, it is characterized by an essentially 'smooth surface' which does not permit its inclusion in the *N. burdigalensis-perforatus* Group. Thus, *N. obtusus* (Sowerby) is not only specifically distinct from *N. perforatus* (de Montfort) but belongs to a different lineage, having close affinity to the *Nummulites gizehensis* Group.

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